Workshop
Dynamical Systems and Applications

in the framework of the project FP7-PEOPLE-2012-IRSES-316338
within the 7th European Community Framework Programme

Hotel PIRAMIDA, Maribor, Slovenia
23 August 2013 - 24 August 2013

Book of Abstracts
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ABSTRACTS
Strongly isochronous two-dimensional holomorphic systems of the ordinary differential equations

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We consider the real autonomous holomorphic systems on the plane with pure imaginary roots of the characteristic equation of the first approximation system.

We give an overview of practically all known results concerning the strong isochronicity of polynomial centers with the indication of the maximum order of strong isochronicity and the initial polar angle.

In particular, quadratic systems, systems with incomplete polynomials of the third, fourth, fifth degrees are considered.
Stability, bifurcation and normal form analysis of predator-prey systems

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The predator-prey system attempts to model the relationship in the populations of different species that share the same environment where some of the species (predators) prey on the others. The well-known problem the Lotka-Volterra model which stands as a starting point for more complex generalizations of predator-prey system lacks to represent realistic models with its unrealistic stability characteristics. Therefore generalizations including higher nonlinear interactions are studied. Changes in the number and stability of equilibrium points in the generalized predator-prey system that lead to qualitative changes in the behavior of the system as a function of some of its parameters are studied by bifurcation analysis. Numerical methods and the approach provided by approximate techniques near equilibrium points are used in the analysis.

References


Regular or chaotic behavior
in a class of hamiltonian systems

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In this paper we study possible regular and chaotic behavior and
approximately conserved quantities in a class of generalized Hénon-
Heiles and classical Yang-Mills Hamiltonians. We present a method
for identifying chaotic and regular behavior by considering the evo-
lution of its tangent space. The method is applied to a class of
Hamiltonian systems to demonstrate the idea. In order to distin-
guish a small positive characteristic exponent from a zero character-
istic exponent, a method for identifying the presence of zero char-
acteristic exponents is suggested. Approximately conserved quan-
tities are investigated via Poisson brackets of the Hamiltonian and
possible invariants.

This work is based on my PhD Thesis supervised by Prof. A. Hacinliyan.

References

[1] O. Ozgur Aybar, I. Birol, A. Hacinliyan, I. Kusbeyzi Aybar, Reg-
ular or Chaotic Behavior in a Class of Hamiltonian Systems, in
preparation
Local bifurcation of critical periods for isochronous centers

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In this talk we discuss the local bifurcation of critical periods for planar differential systems. From 1989 when Chicone and Jacobs founded the basic theory of the critical period bifurcation, many works have been done for several families of systems, specially for polynomial systems. Here we introduce some interesting results and mainly discuss the case that critical periods bifurcating from isochronous centers. For the isochronous centers of an n-th degree homogeneous vector field perturbing in m-th degree time-reversible systems, period-bifurcation functions are presented as integrals of analytic functions which depend on perturbation coefficients and the problem of critical periods is reduced to finding zeros of a judging function.

References


Traveling wave solutions for some reaction-diffusion models

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We study the traveling wave solutions of two kinds of reaction-diffusion models. We discuss the existence of traveling wave solutions with the techniques of qualitative analysis, upper-lower solutions, and monotone iteration method. We also find the precise value of the minimum speeds that are significant to study the spreading speed.

References


The solution of the 1 : -3 resonant center problem in the quadratic case

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The 1 : −3 resonant center problem in the quadratic case is to find necessary and sufficient conditions for existence of local analytic first integrals of the differential system

\[ \dot{x} = x - a_{10}x^2 - a_{01}xy - a_{12}y^2, \quad \dot{y} = -3y + b_{21}x^2 + b_{10}xy + b_{01}y^2. \]

Dividing this problem into two smaller problems, where \( a_{01} = 0 \) and \( a_{01} = 1 \), we gain 25 center cases for \( a_{01} = 1 \) and 11 cases for \( a_{01} = 0 \). The necessary conditions are obtained using modular arithmetics. The main tool to prove the sufficiency of the obtained conditions is the method of Darboux, however some other technics were used as well.
References


The stability of some kinds of generalized homoclinic loops in planar piecewise smooth systems

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In this paper we present some kinds of generalized homoclinic loops in planar piecewise smooth systems. By establishing Poincaré map, we study the stability of these homoclinic loops. For each case, a criteria for stability is given. As applications, several concrete piecewise systems are considered.

References


Identification of focus and center in a 3-dim system

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We identify focus and center for a generalized Lorenz system, a 3-dimensional quadratic polynomial differential system. It is a well-known routine to restrict the system to its a center manifold, but the approximation of the center manifold brings a great complexity in the computation of Lyapunov quantities and their dependence even if the original system is not of high degree. On the other hand, in order to determine if an center-focus equilibrium is a center, those criteria for planar systems such as time-reversibility and integrability are not available on an approximated center manifold. We prove its Darboux integrability by finding an invariant surface, showing that the equilibrium of center-focus type is actually a rough center on a center manifold.

References

Limit cycle bifurcations of a class of piecewise smooth Liénard systems

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In this paper, we consider a class of piecewise smooth Liénard systems as follows

\[
\begin{align*}
\dot{x} &= y, \\
\dot{y} &= -g(x) - \epsilon f(x)y,
\end{align*}
\]

where \(g(x)\) and \(f(x)\) are piecewise polynomials. We classify the unperturbed system into three types and study the bifurcation of limit cycles for the above system. By studying the expansions of the first order Melnikov function, we give some new results on the number of limit cycles in Hopf and homoclinic bifurcations.

References


Dynamical localization, spectral statistics and localization measure in the kicked rotator

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We study the kicked rotator in the classically fully chaotic regime using Izrailev’s $N$-dimensional model for various $N \leq 4000$, which in the limit $N \to \infty$ tends to the quantized kicked rotator. We do not treat only the case $K = 5$ as studied previously, but many different values of the classical kick parameter $5 \leq K \leq 35$, and also many different values of the quantum parameter $k \in [5, 60]$. We describe the features of dynamical localization of chaotic eigenstates as a paradigm for other both time-periodic and time-independent (autonomous) fully chaotic or/and mixed type Hamilton systems. We generalize the scaling variable $\Lambda = l_\infty/N$ to the case of anomalous diffusion in the classical phase space, by deriving the localization length $l_\infty$ for the case of generalized classical diffusion. We greatly improve the accuracy and statistical significance of the numerical calculations, giving rise to the following conclusions: (C1) The level spacing distribution of the eigenphases (or quasienergies) is very well described by the Brody distribution, systematically better than by other proposed models, for various Brody exponents $\beta_{BR}$. (C2) We study the eigenfunctions of the Floquet operator and characterize their localization properties using the information entropy measure, which after normalization is given by $\beta_{loc}$ in the interval $[0, 1]$. The level repulsion parameters $\beta_{BR}$ and $\beta_{loc}$ are almost linearly related, close to the identity line. (C3) We show the existence of a
scaling law between $\beta_{\text{loc}}$ and the relative localization length $\Lambda$, now including the regimes of anomalous diffusion. The above findings are important also for chaotic eigenstates in time-independent systems (Batistić and Robnik 2010, 2013), where the Brody distribution is confirmed to a very high degree of precision for dynamically localized chaotic eigenstates even in the mixed-type systems (after separation of regular and chaotic eigenstates).

References

The study of isochronicity and critical period bifurcations on center manifolds of some 3-dim polynomial systems

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The main topic of this talk is the investigation of a quadratic 3D system of ODEs

\[
\begin{align*}
\dot{u} &= -v + au^2 + av^2 + cuw + dvw \\
\dot{v} &= u + bu^2 + bv^2 + ew + fvw \\
\dot{w} &= -w + Su^2 + Sv^2 + Tw + Uvw 
\end{align*}
\]

(1)

with real coefficients \(a, b, c, d, e, f, S, T\) and \(U\). System (1) was studied already in [1], and further in [2,3], where planar polynomial systems of ODEs appearing on the center manifold of (1) were studied. Using the solutions of the center-focus problem from [1], confirmed in [3] by the so called modular approach [4], we present the investigation of four (at most three parameter-) families of (at most third degree) polynomial systems corresponding to the center varieties of (1). Thus, all systems under consideration correspond to a center manifold filled with closed trajectories (corresponding to periodic solutions of (1)).
In particular, in the talk I shall present the criteria on the coefficients of the system to distinguish between the cases of isochronous and non-isochronous oscillations, considered in [2,3]. Bifurcations of critical periods of the system will be presented as well.

References


Adiabatic invariants and some statistical properties of the time-dependent linear and nonlinear oscillators

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We consider 1D time dependent Hamiltonian systems and their statistical properties, namely the time evolution of microcanonical distributions, whose properties are very closely related to the existence and preservation of the adiabatic invariants. We review the elements of the recent developments by Robnik and Romanovski (2006-2008) for the entirely general 1D time dependent linear oscillator and try to generalize the results to the 1D nonlinear Hamilton oscillators, in particular the power-law potentials like e.g. quartic oscillator. Furthermore we consider the limit opposite to the adiabatic limit, namely parametrically kicked 1D Hamiltonian systems. Even for the linear oscillator interesting properties are revealed: an initial kick disperses the microcanonical distribution to a spread one, but an anti-kick at an appropriate moment of time can annihilate it, kicking it back to the microcanonical distribution. The case of periodic parametric kicking is also interesting. Finally we propose that in the parametric kicking of a general 1D Hamilton system the average value of the adiabatic invariant always increases, which we prove for the power-law potentials. We find that the approximation of kicking is good for quite long times of the parameter variation, up to the order of not much less than one period of the oscillator. We also look at the behaviour of the quartic oscillator for the case of the kick and anti-kick, and also the periodic kicking.
References

Integrability of polynomial systems of ODEs

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Consider polynomial vector fields on $\mathbb{R}^n$ having a singularity at the origin with non-degenerate linear part. We discuss the problems of existence of analytic first integrals, center manifolds, periodic solutions and the problem of stability, and their interconnection. We also explicitly compute center manifolds and first integrals for several families of systems with quadratic and cubic higher order terms and describe computational methods for the study. We also discuss main mechanisms for integrability: Darboux integrability and time-reversibility.

Bifurcations of periodic solutions for some families of polynomial systems are considered as well.

References


Quantum difference–differential equations

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Differential equations which contain the parameter of a scaling process are usually referred to by the name Quantum Difference–Differential Equations. Some of their applications to discrete models of the Schrödinger equation are presented and some of their rich, filigrane und sometimes unexpected analytic structures are revealed.

A Lie-algebraic concept for obtaining basic adaptive discretizations is explored, generalizing the concept of deformed Heisenberg algebras by Julius Wess. They are also related to algebraic foundations of quantum groups in the spirit of Ludwig Pittner.

Some of the moment problems of the underlying basic difference equations are investigated. Applications to discrete Schrödinger theory are worked out and some spectral properties of the arising operators are presented, also in the case of Schrödinger operators with basic shift–potentials and in the case of ground state difference–differential operators.

For the arising orthogonal function systems, the concept of inherited orthogonality is explained. The results in this talk are mainly related to a recent joint work with Sophia Roßkopf and Lucia Birk.
References


Stable periodic points of n-dimentional
diffeomorphisms

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We consider a self-diffeomorphism of (n+m)-space with a fixed hyperbolic point at the origin. The existence of nontransversal homoclinic point is assumed; i.e., intersection of the stable and unstable manifolds contains a point, referred to as a homoclinic point, and this point is a point of tangency of these manifolds.

It follows from results of Sh. Newhouse, B.F. Ivanov, L.P. Shilnikov, S. V. Gonchenko and other authors that, when the stable and unstable manifolds are tangent in a certain way, a neighborhood of the homoclinic point may contain stable periodic points, but at least one of the characteristic exponents for such points tends to zero with increasing the period.

The goal of the talk is to show that under certain conditions imposed mainly on the character of tangency of the stable and unstable manifolds, a neighborhood of the homoclinic point contains an infinite set of stable periodic points whose characteristic exponents are negative and bounded away from zero. An example of such a diffeomorphism was considered in the monograph of V.A. Pliss.
References


Efficient symbolic method to detect Hopf bifurcations in chemical reaction networks

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Determining potential oscillatory behavior of (bio-)chemical reaction networks is closely related to determining the existence of Hopf bifurcation fixed points for positive values of variables and parameters in the corresponding dynamical systems.

On the basis of a classical theorem of Orlando’s on pairs of purely imaginary eigenvalues of a matrix and using combinations of ideas of stoichiometric network analysis with ideas of tropical geometry we have developed (and implemented) a symbolic method for detecting Hopf bifurcation fixed points in chemical reaction networks (for some positive reaction rate parameters). With our fully algorithmic method we could successfully examine several networks of dimension up to 20, and and we have found Hopf bifurcation fixed points for several of them.
Normal forms and versal unfoldings in GLV

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In the case of the full zero degeneracy, the classic Poincare-Birhoff normal form theory is not available. In this talk a predator-prey system with such a degeneracy is considered. A new normal form is given for generalized Lotka-Volterra systems (abbreviated by GLV), which is employed to unfold the degenerate predator-prey system in GLV class. The universality of unfolding is proved by verifying the transversality. Further, all possible bifurcations at the degenerate equilibrium including transcritical bifurcation, Hopf bifurcation and heteroclinic bifurcation are discussed.

References


Stability and bifurcation analysis on a kind of hybrid system

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The mathematical descriptions of many hybrid dynamical systems can be characterized by impulsive differential equations. Impulsive dynamical systems can be viewed as a subclass of hybrid systems and consist of three elements: namely, a continuous time differential equation, which governs the motion of the dynamical system between impulsive or resetting events; a difference equation, which governs the way the system states are instantaneously changed when a resetting event occurs; and a criterion for determining when the states of the system are to be reset. Hybrid and impulsive dynamical systems exhibit a very rich dynamical behavior. In this talk, we are concerned with the stability of the origin and the existence of disconnected limit cycles. Also, we give examples to illustrate how the continuous subsystem and the discontinuous subsystem influence each other, i.e. how the impulses affect the behavior of the orbits to the continuous system.

References


We study the relationship between the multiplicity of a fixed point of a function $g$, and the dependence on $\varepsilon$ of the length of $\varepsilon$-neighborhood of any orbit of $g$, tending to the fixed point. The relationship between these two notions was discovered in Elezović, Žubrinić, Županović in the differentiable case, and related to the box dimension of the orbit.

Here, we generalize these results to non-differentiable cases. We study the space of functions having a development in a Chebyshev scale and use multiplicity with respect to this space of functions. With these new definitions, we recover the relationship between multiplicity of fixed points and the dependence on $\varepsilon$ of the length of $\varepsilon$-neighborhoods of orbits in non-differentiable cases where results from Elezović, Žubrinić, Županović do not apply.

Applications include in particular Poincaré map near homoclinic loop and Abelian integrals.
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